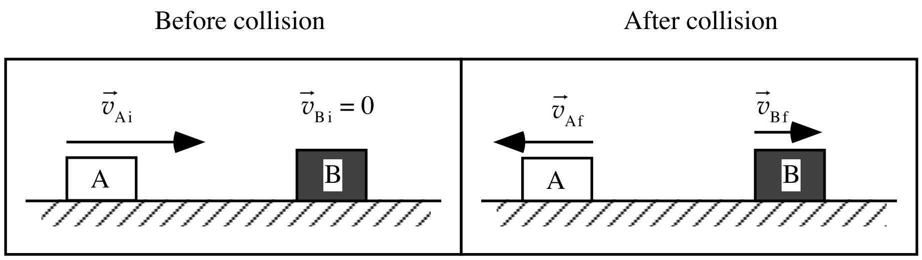
CONSERVATION OF MOMENTUM

Name________________________

1. Two gliders, A and B, collide on a level, frictionless track, as shown below.

   The mass of glider A is less than the mass of glider B (*i.e.,* $m_A < m_B$). The final speed of glider A is greater than the final speed of glider B (*i.e.,* $v_{Af} > v_{Bf}$).



   a. Is the magnitude of the final momentum of glider A (p_{Af}) *greater than, less than,* or *equal to* the magnitude of the final momentum of glider B (p_{Bf})? Draw a momentum vector diagram to support your answer.

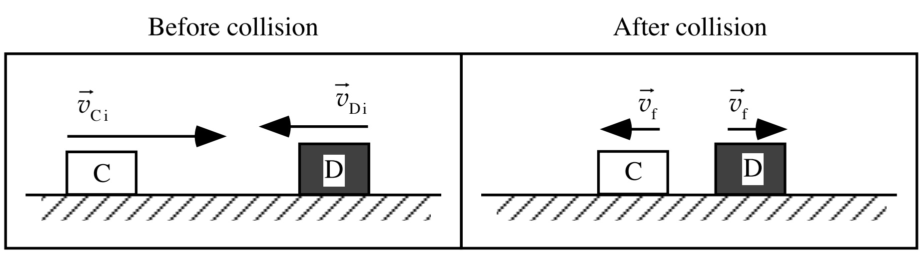
   b. Consider the following statement:

   > "$p_{Af} = p_{Bf}$. What the momentum of A lacks due to its small mass is made up for by its greater speed, because p=mv. The two factors m and v compensate for each other."

   Explain the error(s) in the reasoning.

2. Two gliders, C and D, collide on a level, frictionless track, as shown below.

   The mass of glider C is less than the mass of glider D (*i.e.,* $m_C < m_D$). The initial speed of glider C is greater than the initial speed of glider D (*i.e.,* $v_{Ci} > v_{Di}$). After the collision, Gliders C and D move in opposite directions with the same final speed, v_f.



   Is the magnitude of the initial momentum of glider C (p_{Ci}) *greater than, less than,* or *equal to* the magnitude of the initial momentum of glider D (p_{Di})? Draw a momentum vector diagram to support your answer.

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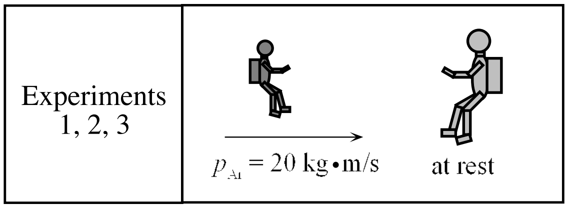
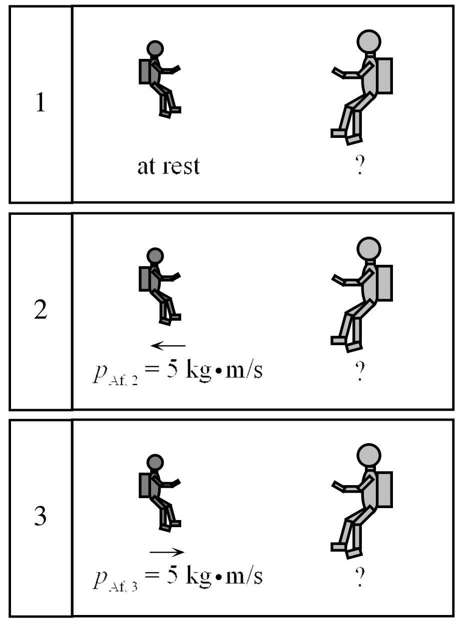
3. Two astronauts, astronauts A and B, participate in three collision experiments in a weightless, frictionless environment. In each experiment, astronaut B is initially at rest, and astronaut A has initial momentum p_{Ai} = 20 kg•m/s to the right. (The velocities of the astronauts are measured with respect to a nearby space station.)

Before



After



The astronauts push on each other in different ways so that the outcome of each experiment is different. As shown in the figure at right, astronaut A has a different final momentum in each experiment.

a. Determine the magnitude of the final momentum of astronaut B in each experiment. Explain.

b. Rank the final kinetic energy of astronaut B in the three experiments. Explain.

c. Is the *total* kinetic energy after the collision in Experiment 2 *greater than, less than,* or *equal to* the *total* kinetic energy after the collision in Experiment 3? ("Total kinetic energy" means the sum of the kinetic energies of the two astronauts.) Explain.

d. Consider the following statement:

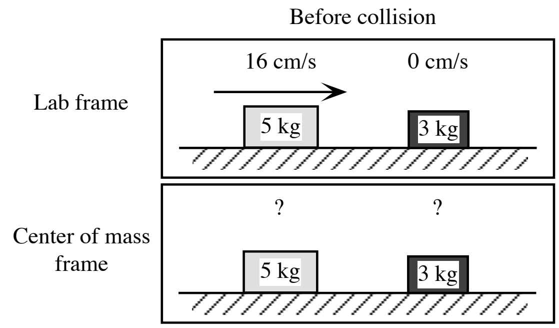
"The momentum of the system is conserved in each experiment because there is no net force on the system. If momentum is conserved, then kinetic energy must also be conserved, because both momentum and kinetic energy are made up of mass and velocity."

One of the sentences above is completely correct. Discuss the error(s) in reasoning in the other sentence.

4. A *single* collision experiment is performed with two gliders, one of mass 5 kg and the other of mass 3 kg, on a level, frictionless track.

In the *laboratory reference frame,* the 5 kg glider moves toward the 3 kg glider with initial velocity 16 cm/s to the right. The 3 kg glider is initially at rest in the laboratory frame.

In the laboratory frame, it is useful to define the *velocity of the center of mass* $\vec{v}_{cm} = \vec{p}_{total}/m_{total}$ and consider how objects are moving relative to the center of mass. The reference frame in which the center of mass is at rest is called the *center of mass reference frame*.



a. Give the direction and magnitude (in cm/s) of the initial velocity of the center of mass of the two-glider system:

i. in the *laboratory frame*. Explain.

ii. in the *center of mass frame*. Explain.

b. Draw the velocity vector that must be added to the initial velocity of the center of mass in the *laboratory frame* in order to obtain the initial velocity of the center of mass in the *center of mass frame*. Give both direction and magnitude, in cm/s. Explain.

c. Generalize your answer to part b to find the initial velocities of both gliders in the *center of mass frame*.

Initial velocity vectors for

	5 kg glider	3 kg glider	center of mass of system
Lab frame	16 cm/s →	0 cm/s	
CM frame			

i. Use the velocities of the gliders in the bottom row of this table to find the total momentum of the system in the *center of mass frame*.

ii. The relationship $\vec{v}_{cm} = \vec{p}_{total}/m_{total}$ applies to measurements made in *any* reference frame. Check that your answers to parts a.ii. and c.i. are consistent with this relationship.

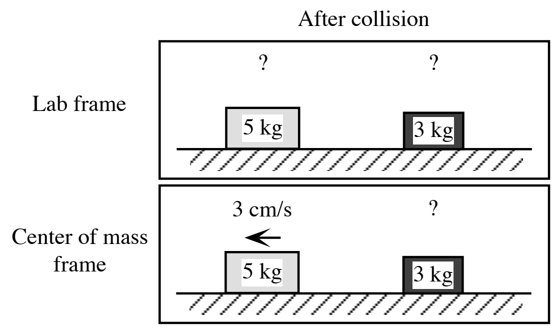
d. Consider the following statement:

"The total momentum of the two-glider system in the lab frame is 80 kg•cm/s to the right. Since momentum is conserved, the total momentum of the system in the center of mass frame must also be 80 kg•cm/s to the right. 'Conservation of momentum' means the total momentum is the same in every frame."

Do you agree or disagree with this statement? Explain your reasoning.

e. In the *center of mass reference frame*, the 5 kg glider moves with final velocity 3 cm/s to the left.

Calculate the final velocity of the 3 kg glider in the *center of mass frame*.



f. Draw the velocity vector that must be added to any object's final velocity in the *center of mass frame* in order to obtain the same object's final velocity in the *laboratory frame*. Give both direction and magnitude, in cm/s. Explain. (*Hint:* How should this vector compare to your answer to part b?)

g. Use your results from parts e and f to complete the table at right.

Use the velocities of the gliders in the top row of this table to calculate the total final momentum of the two-glider system in the *laboratory frame*.

Final velocity vectors for

	5 kg glider	3 kg glider	center of mass of system
Lab frame			
CM frame	3 cm/s ←		

